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TRANSFER PARAMETERS IN THE WATER/FORAGE/MOOSE PATHWAY

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ABSTRACT

Moose tissue samples and associated water and drinking water samples were collected from the Serpent River Drainage Area (Study Area) and outside of the watershed (Controls) during the fall of 1985. The concentrations of lead-210, polonium-210, radium-226, thorium and uranium were determined for both the study area and control samples. The radionuclide radium-226 was evaluated in the drinking water, vegetation and moose tissue to determine concentration factors. No statistical difference was found between study and control samples. Concentration factors from vegetation to moose tissue were found to range from 0.036 to 3.03 depending upon tissue type. Radionuclide concentrations found in this study were shown to be within known background levels.

RÉSUMÉ

Des échantillons de tissus d'orignal et des échantillons d'eau s'y rapportant et d'eau potable ont été prélevés durant l'automne 1985 dans le bassin de la rivière Serpent (aire d'étude) et à l'extérieur de la ligne de partage des eaux (contrôle). Les concentrations de plomb 210, de polonium 210, de radium 226, de thorium et d'uranium ont été précisées aussi bien pour les échantillons de l'aire d'étude que pour les échantillons de contrôle. On a évalué le radionucléide radium 226 dans l'eau potable, la végétation et les tissus d'orignal afin de déterminer les facteurs de concentration. Aucun écart statistique n'a été noté entre les échantillons de l'étude et ceux du contrôle. On a constaté que les facteurs de concentration dans les tissus d'orignal par rapport à la végétation variaient de 0,036 à 3,03, selon le type de tissu. Les concentrations de radionucléides constatées dans la présente étude correspondaient aux niveaux connus du fond naturel de rayonnement.

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1.0 INTRODUCTION

The objective of this study was to determine concentration factors for the radionuclide Radium^{226} in the drinking water to forage moose pathway. To carry out this objective, Ra^{226} levels were determined in samples of moose tissue and related drinking water and forage samples from within the study area (the Serpent River drainage area) and in controls (defined as 50 to 60 miles upstream).

Levels of the radionuclides Polonium^{210}, Lead^{210}, Radium^{226}, Uranium and Thorium were determined in both study area and control moose tissue samples and tested for significant differences. Finally the radionuclide levels obtained were compared with known background levels.

1.1 Study Components

The successful completion of a study of this nature required the inclusion of several related but distinct tasks. Acceptance of a finalized project scope allowed the refining of these distinct tasks. The tasks included:

i) Collection of water and vegetation samples
ii) Public awareness campaign
iii) Collection of Moose tissue samples
iv) Definition of analytical scheme
v) Interpretation of data and reporting

Each of these will be described and discussed in pertinent sections below.

2. SAMPLE METHODOLOGY

2.1 Water and Forage Sample Regime

In determining the appropriate species to sample for the forage analysis, it was very important to consider the food preferences exhibited by Moose in relation to seasonal variability and known preferences in that specific part of North America. To determine the types of plants to sample a preliminary literature search was carried out. This information was augmented by discussions with recognized Moose experts (OMNR Maple Research Station), as well as discussions with the local Ontario Ministry of Natural Resources (OMNR) office in Blind River. Results of this inquiry indicated that Moose show a considerable seasonal variation in the types of food eaten. Generally though, this could be divided into two main categories:

i) Aquatic macrophytes
ii) Terrestrial woody species

i) Aquatic Macrophytes

In northeastern Minnesota it was found that aquatic vegetation may provide most of the Moose diet in June.[1] Examination of favoured Moose feeding areas indicated that yellow pond lily (Nuphar variegatum) was the most favoured of the aquatic plants, while pond weeds, wild rice and water milfoil were also favoured. Fraser and Hristienko[2] similarly found that in a study of Moose in Sibley Provincial Park, Ontario, that yellow pond lily was favoured along with the pond weeds specifically Potamogeton alpinus and P. epihydrus. Peterson[3] found that in Algonquin Park the most important aquatic food species included yellow pond lily, watershield, eel grass, bur-reed and the pond weeds.

Based upon this information, it was decided to use yellow water lily (Nuphar variegatum) and one of the pond weeds (whichever appeared most

abundantly) as the aquatic species representative of the Moose diet. Use of the species was corroborated in the field prior to sampling and if differences were noted, then other species which were being actively grazed upon were taken. In some cases, a third species was also sampled to ensure flexibility within the analysis.

ii) Terrestrial Woody Species

Foraging on woody species is carried on to some degree throughout the year. However, there are seasonal differences in the species most favoured and the parts eaten. In one study[1], aspen was determined most important in June (mainly the young leaves) while willows, mountain maple, white birch and fire cherry were more important through July and August. Red-osier dogwood became more important in fall. Balsam fir and beaked hazel were primarily winter forages with fir especially important in March. Brusnyk and Gilbert[4] found that in Chapleau Game Preserve in Ontario, of the ten (10) most common browse species available, beaked filbert, paper (white) birch, mountain maple, trembling aspen and willow constitute about 87 per cent of the total recorded browse consumed by Moose. American mountain ash had the highest preference value followed by mountain maple and paper birch.

Based upon these findings it was decided that either mountain maple or paper (white) birch or red-osier dogwood was to be used as one of the terrestrial species sampled. The final decision on which species to sample was arrived at following corroboration of active grazing over the previous year on the sample sites during active collection.

Balsam fir was the other terrestrial woody species chosen, for it alone seems to provide a large proportion of the winter diet of Moose. Twigs and leaves were gathered to form the sample.

2.1.1 Study Area Samples

The study area (as delineated on Figure 2) contains three sub- basins as part of the overall Serpent River Drainage Basin. These include:

1) Turtle Lake sub-basin
2) Lower Serpent River sub-basin
3) Little Serpent River sub-basin

For sampling purposes, these areas were defined as:

Area A - East half of Turtle Lake sub-basin
Area B - Entire Lower Serpent River sub-basin
Area C - North Half of Little Serpent River sub-basin
Area D - South half of Little Serpent River sub-basin

Sections (A-D) covered approximately equal areas. Based upon discussions with local hunters and the district office of OMNR, it was felt that the western half of Turtle Lake sub-basin could be excluded, since historical records indicated little hunter success in this section.

The first stage of the sample collection involved a reconnaissance of the sections to familiarize the sample collector with the distribution of access routes (both road and water).

Every opportunity was taken to talk with residents about this program and to ask for information regarding high hunter success locations, locations of hunting camps and where possible delineate present active use areas.

Each section was investigated as thoroughly as possible given the time and budgetary constraints for the program. Where possible, information regarding Moose activities was used to increase the efficiency of sample collection. Samples were taken only from sites where evidence of present or past

usage by Moose existed. In some cases active grazing on plants was noted by the sample collector. Choice of species to sample had been tentatively determined from the literature search results and follow-up discussions, however the actual species sampled were those which had been or were being used by Moose in the specific area.

Sample sites within each section (where possible) were chosen such that they represented a fairly equal distribution within each section.

Sampling consisted of gathering the entire (above soil/sediment) portion of the plant species, lightly shaking the specimen to remove the majority of surface water and placement in a clean plastic bag. A total of 500 to 1000 grams of material was collected, per species, per sample site. Where possible, plants were taken from as many different aquatic plant aggregates as possible. Two or three different species were collected in this manner and each species placed in separate sample bags. Samples were frozen as soon as possible to ensure maximum sample integrity.

Terrestrial sampling involved the requirement of gathering both winter and other season feed species. The methodology consisted of trimming off first and second year growth from a tree, the cut-off portion was placed directly into a clean, plastic sample bag. A total of 500 to 1000 grams of material was collected per sample and each sample was comprised of a mix of portions from a minimum of ten individual trees within a 20 m^2 zone. All samples were frozen as soon as possible.

Water sample collection consisted of collecting water from lakes adjacent to the sample site in clean four-litre plastic sample jars. Water was taken from approximately one-third metre under the surface of the water source. Containers were rinsed in the sample water prior to the actual collection. Water samples were preserved with ten mls per litre of concentrated nitric acid and stored in a cool place.

2.1.2 Control Samples

The concept of control data is to have values of comparable parameters which are removed from the study area in question. It was determined that the best approach would be to collect the vegetation and water samples from sites where a Moose tissue sample had already been collected. The time of year involved precluded sampling for aquatic macrophytes. However, terrestrial vegetation and water samples were collected from selected sites adjacent to control samples. Sample collection methodology was equivalent to the study area collection.

2.2 Public Awareness Program

In approaching the Moose tissue sample collection aspect of the project, public awareness and participation were key components to a successful program. With the assistance of OMNR, hunters who had acquired adult Moose tags through the OMNR annual Moose lottery system draw were targeted for assistance in obtaining the required tissue samples. Hunter participation was essential in recording the necessary field data pertaining to the kill site location, animal health, sex, age and size information, as well as ensuring that these individuals were aware of the proper collection procedures to follow. A public awareness campaign was therefore developed by MacLaren and implemented prior to the 1985 Moose hunting season.

From the OMNR 1985 adult Moose tag recipients computer listings, a complete file of 300 hunters' names, addresses, and hunting tag type was compiled for those hunters who were licenced to hunt in the Serpent River study area (OMNR Wildlife Management Unit 37). Emphasis was placed on those hunters who resided in Elliot Lake and those that lived in communities that bordered the designated study area. Individuals were contacted through registered mail inviting them to participate in the Serpent River Area Moose Collection 1985. These hunters were provided with an information package that included a pamphlet giving a brief description of the study, a hunter information request form, a detailed map indicating the boundaries of the study area, a

covering letter and a stamped self-addressed envelope to reply to the request for participation (Appendix 6.1). Incentives for participation were also outlined within the information package which indicated that the hunter would be rewarded for efforts he or she may put forth to ensure the success of the outlined collection program. Each hunter who actively participated in the project (by obtaining sample collection bags from any of the locations listed within their information package) would receive a complimentary blaze orange hunting hat. Those hunters who successfully obtained a complete tissue sample set as outlined in the package would receive a reversible blaze orange hunting vest.

Upon initial start-up of the collection program in Elliot Lake, MacLaren's field crew with the assistance of the local AECB office collected all the hunters' replies from a post-office box that had been obtained in Elliot Lake for convenience and efficiency. Each reply was examined and those hunters who were interested in participating in the program were contacted by telephone and informed that sampling packages could be obtained at the locations listed on the pamphlet. These locations included the Atomic Energy Control Board Office, Elliot Lake; the Inn-on-the-Lake Hotel, Elliot Lake; the Wheel Inn, Serpent River; and the Ontario Ministry of Natural Resources District Office and Conservation Officers Office, Blind River and Elliot Lake, respectively.

In addition to the above locations a marked vehicle travelled to various locations within the study area setting up an information and contact check station for hunters travelling throughout the area (Appendix 6.1.) A second vehicle made contact with hunting parties throughout the study and control areas by visiting known hunting camps and traditional hunting areas. The personal contact of both the mobile information station and the field contact person allowed for the requirements of the collection program to be relayed on a one-to-one basis, as well as increasing coverage of the program.

During the week prior to the opening of the hunting season and during the first week of the season, the local newspaper in Elliot Lake ran an article explaining the details and scope of the collection program. The article helped to ensure full coverage of the project within the surrounding communities of Elliot Lake and helped to inform hunters who might be willing to provide control samples (control samples being defined as animals taken 60 to 70 miles outside the study area boundaries) of the pertinent details.

To complete the information and sample bag package coverage, OMNR Conservation Officers from Blind River were also briefed on the intent of the collection program and were encouraged to help hunters with questions pertaining to the program. Sampling packages were given to the Conservation Officers to distribute to authorized hunters, as hunter/officer encounters are frequent during the hunting period.

2.3 Moose Tissue Collection

Proper handling, labelling and delivery of the Moose tissue samples from successful hunters was of paramount importance in this study. Labelled sample bags, bag ties, and a data sheet (pamphlet) were all included in the hunters sampling package that were distributed prior to and during the hunting season. Each hunter was asked to carry their sampling packages during the hunt in order to sample the required Moose tissue directly from the animals at the kill site. A successful hunter was to obtain approximately 1-2 lbs (400-800 grams) each of liver, kidney, heart, muscle, skin, and bone while field dressing his/her freshly killed animal.

Samples were to be placed unwashed in the appropriately labelled sample bags. The samples once complete were to be taken either to the nearest drop-off station within three days of the kill or be frozen, as soon as possible, to be dropped off or arrange for pick-up at a convenient time. Data pertaining to both the sample specimen and the kill site was recorded

on the hunters data sheet and placed with the composite sample collected by the hunter.

Samples were collected on a daily basis by MacLaren personnel and stored in freezer facilities in Elliot Lake. Each sample was checked for sample size and completeness and the information from hunters data sheets was logged in a master file. Any incomplete information or sample set was noted and the corresponding hunter was contacted in order to obtain the missing data if at all possible. The Moose tissue collection phase was terminated at the end of October 1985 (Appendix 6.1).

2.4 Radionuclide Analysis

It is important, in obtaining the required nuclide levels in the various samples, that a detection method be used that has the required sensitivity.

Previous studies have found Uranium and Thorium at levels in the range of nanograms/gram sample[5]. It was proposed therefore that, for Uranium and Thorium, instrumental neutron activation be used. Expected levels of the other three nuclides, Ra^{226}, Pb^{210} and Po^{210} appeared to be in the 0.003 Bq/g range and would therefore be performed by standard radiochemical analysis, proven to have lower limits of detectability of 0.02 Bq for Pb^{210}, 0.005 Bq for Po^{210} and 0.005 Bq for Ra^{226}.

All sample analysis was carried out by the analytical chemistry laboratory of the Saskatchewan Research Council (SRC). Detection and precision limits given for sample analyses, at SRC, are given in Table 1.

For Ra^{226} the samples were decomposed by potassium pyrosulphate fusion. Radium was isolated by first precipitating with lead sulphate and then selectively precipitating with barium sulphate. The radium in the precipitate was determined by alpha spectroscopy[6].

TABLE 1

DETECTION AND PRECISION LIMIT LEVELS

FOR RADIOCHEMICAL PROCEDURES

	Detection Limit[2]	Precision Limit[3]
Ra^{226}	0.005 Bq	0.18-0.37 Bq ± 10% >0.37 Bq ±6%
Pb^{210}	0.02 Bq	0.18-0.37 Bq ±8% >0.37 Bq ±4%
Th (N.A.A.)	0.1 µg/g	0.1-0.5 ±10% >0.5 ±5%
Po^{210}	0.005 Bq	0.18-0.37 Bq ±8% >0.37 Bq ±4%
U (D.N.C.)	0.10 µg/g	>5 µg ±5% >20 µg ±2%

1. Saskatchewan Research Council
2. Detection limit or sensitivity of method, value given is lowest limit detectable
3. Precision limit or reproducibility factor which is the standard deviation given as a percent as shown.

Samples analyzed for Lead^{210} were digested by $HNO_3/HClO_4$. The Bi^{210} was extracted with diethylammonium diethyldithiocarbamate (DDTC) from 2M HCl solution. After evaporation, the organic extract was dissolved in nitric acid, diluted and BiOCl precipitated as the final counting form of Bi^{210}. The quantity of Bi^{210} present was determined by beta counting with a low background counting system. The Pb^{210} concentration was calculated from the equilibrium existing between it and the Bi^{210} [6].

Samples analyzed for Po^{210} were also digested with a $HNO_3/HCLO_3$ solution. The Polonium was plated onto silver or nickel from a 0.5 N HCl solution. The metal disk was counted by alpha spectroscopy to determine the amount of Po^{210}. Standards were prepared in the same manner as the sample[6].

Both total Thorium and Uranium were analyzed by standard neutron activation techniques. No sample preparation was required[6].

2.4.1 Quality Assurance

It is especially important in this type of project to ensure the highest possible quality of work as the results may be instrumental in helping to estimate the dose from this pathway from uranium tailings.

Saskatchewan Research Council are actively involved in interlaboratory comparisons for quality assurance with:

1. United States Environmental Protection Agency.

2. Health and Welfare Canada, Bureau of Radiation and Medical Services.

Duplicate samples of moose tissue were sent as blind samples to the SRC laboratory to obtain a further quality control check.

3.0 RESULTS AND DISCUSSION

3.1 Water and Forage Sample Results

A listing of the water and forage samples taken is given in Table 2. The table outlines the type and number of samples taken and whether the sample is from the study area or control area. The study area was subjectively delineated into four (4) segments (A to D) and these areas are reflected in Table 2. Distribution of the sample sites for the control samples, as well as within each segment of the study area, was determined as outlined in Section 2.1. Figure 2 shows the distribution pattern of the sample sites and the locations of the samples which were actually analyzed for radionuclide content. The control samples taken corresponded to areas for which Moose tissue samples were already available. These water and vegetation samples were taken later in the fall.

Field reconnaissance for the aquatic plants indicated that moose were actively feeding on yellow water lily, pondweeds, small water lily (Brasenia) and pickerel weed.

Heavy grazing (to the point of decimation of whole beds) was observed on pickerel weed wherever it was found within the whole study. In terms of distribution, pickerel weed and yellow small water lily were the two aquatic species found most frequently.

It is axiomatic that Moose food habits change over the seasons with one species (balsam fir) contributing the majority of winter feed. Balsam fir was therefore collected at each site. Field reconnaissance determined that Moose had been actively feeding on a number of other terrestrial plant species. From these other terrestrial species, white birch was chosen and collected at as many sites as possible. In addition the sample collector also gathered manitoba maple and/or red maple where applicable.

TABLE 2

COMPLETE LISTING OF DRINKING WATER AND FORAGE SAMPLES COLLECTED

STUDY AREA SECTION	NUMBER OF SAMPLES	DESCRIPTION
STUDY AREA 'A'	7	DRINKING WATER
	4	YELLOW WATER LILY
	3	PICKERELWEED
	2	PONDWEED
	1	BRASENIA
	7	WHITE BIRCH
	7	BALSAM FIR
STUDY AREA 'B'	7	DRINKING WATER
	4	YELLOW WATER LILY
	6	PICKERELWEED
	1	PONDWEED
	1	BRASENIA
	6	WHITE BIRCH
	6	BALSAM FIR
	1	MOUNTAIN MAPLE
	1	RED MAPLE
STUDY AREA 'C'	6	DRINKING WATER
	4	YELLOW WATER LILY
	2	PICKERELWEED
	3	PONDWEED
	3	WHITE BIRCH
	6	BALSAM FIR
	4	MOUNTAIN MAPLE
STUDY AREA 'D'	5	DRINKING WATER
	4	YELLOW WATER LILY
	2	PICKERELWEED
	3	WHITE BIRCH
	4	BALSAM FIR
	2	MOUNTAIN MAPLE
CONTROL AREA	7	DRINKING WATER
	7	WHITE BIRCH
	7	BALSAM FIR
	1	YELLOW WATER LILY

3.2 Public Awareness

The public awareness campaign was well received as evidenced by the level of participation. In total, from the four contact locations, the mobile field units, and contact with field personnel, 226 sampling packages were distributed (each accompanied with the complimentary hunting hat) to hunters in the Elliot Lake area. The response to the program was overwhelming as the allotted number of sampling packages had been given out by the second week of the hunting season. Actual tissue samples were being returned to MacLaren from the various drop-off locations within the first week of the hunt. With hunters dropping off Moose tissue samples to the various locations indicated, MacLaren field staff routinely (on a daily basis) completed daily pickups, compiled the data on those samples received and stored the samples in freezer facilities in Elliot Lake.

The field sampling program was terminated at the end of October. MacLaren had at this time received a total of 48 samples. Letters were sent to all hunters and parties that were involved in the program (Appendix 6.1) extending appreciation and thanks for the overwhelming response from the hunting community which resulted in a very successful field collection. Hunters, who were successful in obtaining complete sample sets were notified that they would receive the complimentary hunting vest as soon as the necessary arrangements (size of the vest and proper address for shipment purposes) were complete. It was later decided that all hunters who submitted samples, complete or incomplete, would receive a vest because of the outstanding efforts that were put forth by the hunters to ensure a successful Moose sample collection. These additional hunters were also notified and all vest recipients had been awarded by April 1986.

3.3 Moose Tissue Collection

Response to the Moose tissue collection by participants was excellent. Table 3 provides a complete listing of the moose tissue sample sets received

TABLE 3

COMPLETE LISTING OF MOOSE TISSUE SAMPLES COLLECTED

STUDY AREA SECTION	NUMBER OF SAMPLES	DESCRIPTION
STUDY AREA 'A'	5 BULL MOOSE	4 COMPLETE
		1 INCOMPLETE
	3 COW MOOSE	3 COMPLETE
		0 INCOMPLETE
STUDY AREA 'B'	1 BULL MOOSE	1 COMPLETE
		0 INCOMPLETE
	0 COW MOOSE	0 COMPLETE
		0 INCOMPLETE
STUDY AREA 'C'	1 BULL MOOSE	1 COMPLETE
		0 INCOMPLETE
	1 COW MOOSE	1 COMPLETE
		0 INCOMPLETE
STUDY AREA 'D'	1 BULL MOOSE	1 COMPLETE
		0 INCOMPLETE
	0 COW MOOSE	0 COMPLETE
		0 INCOMPLETE
CONTROL AREA	28 BULL MOOSE	18 COMPLETE
		10 INCOMPLETE
	12 COW MOOSE	9 COMPLETE

over the course of the program. A total of 48 samples had been received by the third week of the hunting season and an additional 4 samples were received in December after the sampling program had been terminated. Thus in total 52 samples were collected from the sampling packages distributed. Of these samples, 12 of the total were animals sampled within the study area with 11 of those being complete samples. Moose sampled from outside the study area (possible control samples) accounted for 40 of the samples, 27 being complete samples. Twelve moose sample sets (7 study area samples and 5 control samples) were chosen from the total complement for radionuclide analysis. Figure 1 shows the kill locations of the moose samples which were analyzed for radionuclide content as described in Section 3.4.

3.4 Radionuclide Analysis

Complete analysis, which included the 5 radionuclides on the 6 different tissue types was carried out on 5 of the study and 2 of the control sample sets. Two sample sets (one study area and one control area) each were processed for Quality Assurance as described in Section 2.4.1.

An additional three sample sites (two control area and one study area) were analyzed for Ra^{226} only in the kidney, muscle, liver and bone and for Uranium and Thorium in the skin. Table 4 provides a summary of the samples analyzed. These determinations are detailed by sample designate and tissue type, and geometric standard deviation for each analyte. In some cases the sample set did not provide the required amount of material for total analysis thus accounting for the discrepancy in total numbers of samples per tissue type.

Results from the laboratory were reported on an as-received (wet weight) basis for Pb^{210} and Po^{210}, and on an ash basis for Ra^{226}, Thorium and Uranium. For comparative purposes, in Table 4, all values were converted to wet weight. Drinking water samples corresponding to the analyzed moose samples were analyzed for Ra^{226} levels. There were 9 water samples analyzed and 8 of these had the same Ra^{226} levels (.005 Bq/l) these therefore have not been included in Table 4.

TABLE 4

SUMMARY OF RADIONUCLIDE ANALYSIS ON MOOSE TISSUE AND FORAGE SAMPLES
VALUES GIVEN AS GEOMETRIC MEAN AND GEOMETRIC STANDARD DEVIATION

ANALYTE		LEAD 210			POLONIUM 210			RADIUM 226			THORIUM			URANIUM		
SAMPLE DESIGNATE TISSUE TYPE	NUMBER OF SAMPLES	GEOMETRIC MEAN	S.D.	NUMBER	GEOMETRIC MEAN	S.D.	NUMBER	GEOMETRIC MEAN	S.D.	NUMBER	GEOMETRIC MEAN	S.D.	NUMBER	GEOMETRIC MEAN	S.D.	NUMBER
		(Bq/g)			(Bq/g)			(Bq/g)			(Bq/g)			(Bq/g)		
STUDY AREA																
KIDNEY	6	.00262	2.466	6	.00404	2.2177	7	.0003	1.667	6	.0011	1.557	6	.0015	1.740	
HEART	6	.00089	1.2193	6	.00054	2.0455	6	.0002	2.871	6	.0009	1.07	6	.00190	1.3378	
MUSCLE	6	.00096	1.0955	6	.00046	1.2328	7	.0002	3.058	6	.0016	3.169	6	.0031	2.068	
LIVER	6	.00703	12.142	6	.00476	1.8404	7	.0006	1.671	6	.0010	1.605	6	.0037	2.338	
SKIN	6	.00202	2.0874	6	.00214	2.097	6	.0004	2.109	7	.0023	4.076	7	.0069	2.436	
BONE	5	.01610	2.0361	5	.01274	2.3227	6	.0097	6.653	5	.0415	1.109	5	.0954	1.379	
WHITE BIRCH	-*	-	-	-	-	-	6	.0061	1.360	-	-	-	-	-	-	
BALSAM FIR	-	-	-	-	-	-	6	.0034	1.167	-	-	-	-	-	-	
YELLOW WATER LILY	-	-	-	-	-	-	2	.0033	1.515	-	-	-	-	-	-	
PICKEREL WEED	-	-	-	-	-	-	4	.0034	2.535	-	-	-	-	-	-	
PONDWEED	-	-	-	-	-	-	1	.0012	1.000	-	-	-	-	-	-	
CONTROL AREA																
KIDNEY	3	.00182	3.4738	3	.00493	2.2761	5	.00042	2.5700	3	.0010	1.046	3	.00395	2.219	
HEART	3	.00077	1.4528	3	.00052	2.3083	2	.00045	1.151	2	.0009	1.157	2	.00184	1.157	
MUSCLE	3	.0010	1.000	3	.00055	1.7022	5	.00015	2.972	3	.0009	1.136	3	.00174	1.136	
LIVER	3	.00783	2.3094	3	.00737	3.2584	5	.00029	4.355	3	.0011	1.206	3	.00296	1.713	
SKIN	3	.00271	2.3917	3	.00245	3.2048	3	.00027	6.039	4	.00270	18.724	4	.0086	8.311	
BONE	3	.03915	1.2918	3	.02621	1.2639	4	.0375	3.449	3	.0378	1.325	3	.0756	1.325	
WHITE BIRCH	-	-	-	-	-	-	5	.0174	4.21	-	-	-	-	-	-	
BALSAM FIR	-	-	-	-	-	-	5	.0115	2.876	-	-	-	-	-	-	
YELLOW WATER LILY	-	-	-	-	-	-	1	.0008	1.00	-	-	-	-	-	-	

* - indicates sample not analysed for analyte

Appendix 6.2 provided details of all moose tissue, forage and water samples analyzed.

3.4.1 Statistical Analysis of Results

In environmental samples, the distribution of data is frequently assumed to be lognormally distributed, i.e. the log transform of the data is distributed normally. This is a realistic assumption in studies where negative numbers are not realistic (i.e. concentrations less than zero) and there is no upper bound to the data (i.e. high concentrations can be at any level).

In this study, with the small sample group, it is not possible to test the assumption that the data belong to a lognormal population or any other distribution . It is assumed however, that the data are lognormally distributed for the first series of statistical tests. Subsequent tests, (Mann-Whitney tests), were used without an assumption of underlying distribution shape.

All statistical tests were carried out on the values as reported by the laboratory, that is, values per gram wet weight for Pb^{210} and values per gram ash weight for the other radionuclides.

3.4.1.1 Parametric Test

In testing whether or not the study group had higher concentrations than the control group, with the lognormal assumption, geometric means and standard deviations were calculated. The procedure involved is a standard technique[7] and therefore is not discussed here. Results are shown in Table 4 and Appendix 6.2.

Having determined the geometric means and standard deviations, it was necessary to determine if the population variances of the samples were equal before testing for differences in the mean values.

The procedure for determining the equality of population variances is the F-test (Fisher test)[7]. All data sets were tested at a 95% confidence level. Results of the tests are shown in the first column of Table 5.

The testing was then continued to determine if the study group data sets had higher concentrations than the control group data sets. In data sets where the variances were equal, a standard two means "t" test was used. For those where the populations were not of equal variance, a variation on the standard test called "Welch's approximation" was used[8]. This latter test modifies the degrees of freedom in order to test for the differences in means. Details and an example of these procedures are given in Appendix 6.3.

Column 2 of Table 5 also shows the results of the various tests. As can be seen, the study group (both animals and plants) did not have higher concentrations of radionuclides than the control groups.

3.4.1.2 Non Parametric Tests

Inherent in the previous parametric statistical tests was the assumption that the data were drawn from sample populations that are lognormally distributed. Due to the limited sample size, this is only an assumption based on experience with previous environmental samples.

If the population was not normal (or lognormal) an assumption of normality can lead to incorrect interpretations of the results. Another statistical test procedure (non-parametric) requiring only a continuous distribution, but no shape assumptions, was used to compare the study and control groups.

The most useful of these for the current testing is the Mann-Whitney test[7]. In cases where these tests are used on normal distributions, parametric tests are considered more powerful by about 5%[9], but in cases where the assumptions for parametric tests are violated, the Mann-Whitney test may be more powerful[10].

TABLE 5

POPULATION VARIANCE TESTING AND GEOMETRIC MEANS TESTING

Sample Set	Equality of Population Variance[1]	Study Group Geometric Mean is not different from Control Group[1] Geometric Mean
Moose (Pb^{210})		
Kidney	equal	yes
Heart	equal	yes
Muscle	-[2]	-
Liver	equal	yes
Skin	equal	yes
Bone	equal	yes
Moose (Po^{210})		
Kidney	equal	yes
Heart	equal	yes
Muscle	not equal	yes
Liver	equal	yes
Skin	equal	yes
Bone	equal	yes
Moose (Ra^{226})		
Kidney	equal	yes
Heart	equal	yes
Muscle	equal	yes
Liver	equal	yes
Skin	equal	yes
Bone	not equal	yes
Moose (Thorium Total)		
Kidney	-	-
Heart	-	-
Muscle	-	-
Liver	-	-
Skin	equal	yes
Bone	-	-
Moose (U Total)		
Kidney	not equal	yes
Heart	not equal	yes
Muscle	-	-
Liver	equal	yes
Skin	equal	yes
Bone	-	-
Vegetation (Ra^{226})		
White Birch	not equal	yes
Balsam Fir	not equal	yes
Yellow Lily	-	-
Pickerel Weed	-	-
Pond Weed	-	-

(1) At 95% confidence
(2) Standard deviation values where zero and SD precluded meaningful testing.

A description and example of the Mann-Whitney test is given in Appendix 6.3. The test was used for the hypothesis that the study group had higher concentrations than the control group. The test was performed at a 97.5% confidence level. In all cases, the hypothesis was rejected, i.e. the study group did not have higher concentrations than the control group. These results were obtained for all Moose tissue samples and vegetation samples for all of the radionuclides analytes.

3.4.2 Transfer Coefficients

Transfer coefficients are only reported for radium as this was the only radionuclide analyzed for in the vegetation and water samples.

In the previous section, it was shown that there was no statistical difference between the concentration in the tissue of the study group and the concentrations in the tissue of the control group. As a result, the group data was combined to calculate a total geometric mean and standard deviation. Results are shown in Table 6 for Ra^{226} in each tissue type.

In comparing the vegetation data, no statistical difference was found between the plant species and between the control and study groups. As a result, average concentrations were calculated for the total (30) vegetation samples. These results are shown in Table 6.

Using this data, the equilibrium transfer coefficient, defined as

$$f = \frac{\text{conc. in tissue}}{\text{conc. in vegetation}}$$

were calculated along with a 95% confidence interval of the transfer coefficient based on the 95% confidence intervals of the individual concentrations. Equilibrium transfer coefficient was only determined for the forage to moose tissue route, as the drinking water component was considered to be small.

TABLE 6

SUMMARY OF Ra^{226} DATA (Bq/g)

	n	Geometric Mean	Geometric Deviation
Kidney	12	0.0004	2.004
Heart	8	0.0003	2.553
Muscle	12	0.0002	2.95
Liver	12	0.0004	2.799
Skin	9	0.0004	2.999
Bone	10	0.017	5.662
Vegetation	30	0.0056	2.962

The results of these calculations are shown in Table 7. These values are considered to be very low[11]. Not unexpectedly, the bone transfer coefficient is higher than the others. This is due to the fact that radium behaves in a similar fashion to calcium and, as a result, concentrates in the bone.

The radionuclide levels in both the study and control samples (vegetation, moose and water) were consistent within the range of normal background levels[12]. This is demonstrated in tables 8 and 9, where a comparison is shown between background radionuclide levels in non-anthropogenic areas and the current study.

3.4.3 Quality Assurance

The protocol and rationale for Quality Assurance were discussed in Section 2.4.1. One control sample and one study sample, respectively, had each tissue type divided evenly and duplicate samples sent to the same laboratory (SRC) as blind samples. Table 10 details the results of this analysis.

The Quality Control results as given in Table 10 display some variations between the values of some of the analytes. However, the values displayed are quite low (very close to detection limits) and this may account for the apparent discrepancy, conversely there may be the possibility that sample contamination occurred at some point in the handling process.

TABLE 7

EQUILIBRIUM TRANSFER COEFFICIENTS FOR Ra^{226}

IN MOOSE TISSUE FROM VEGETATION

Transfer Tissue	Coefficient[1]	95% Confidence Interval
Kidney	0.07	0.065 to 0.075
Heart	0.053	0.036 to 0.078
Muscle	0.036	0.027 to 0.048
Liver	0.07	0.054 to 0.091
Skin	0.07	0.045 to 0.11
Bone	3.03	1.30 to 7.04

(1) dimensionless (Bq/g / Bq/g) on a wet weight basis

TABLE 8

COMPARISON OF Ra^{226} CONCENTRATIONS

IN CURRENT STUDY VEGETATION AND WATER SAMPLES WITH

BACKGROUND VEGETATION AND WATER VALUES

Sample	Current Study Range of Samples	National Uranium Tailings Program Background Study[1] Range of Samples
Terrestrial Vegetation (Bq/g)	< 0.005 to 0.042	< 0.001 to 0.1
Aquatic Vegetation (Bq/g)	< 0.001 to 0.0054	< 0.01 to 3.9
Water (Bq/L)	.005 to .06	< 0.001 to 0.35

[1] Ref. 12

TABLE 9

COMPARISON OF LEVELS BETWEEN MOOSE TISSUE RADIONUCLIDE CONCENTRATIONS AND BACKGROUND TERRESTRIAL FAUNA

Sample		Current Study range of samples	National Uranium Tailings Program Background Study[1] Range of Samples
Moose Tissue[2]	U-tot (ppm)	0.008 to 0.16	< 0.02 to 0.09
	Th-tot (ppm)	0.0004 to 0.21	< 0.1 to 1.0
	Ra^{226} (Bq/g)[3]	<0.00005 to 0.002	< 1×10^{-4} to 0.6[3]
	Po^{210} (Bq/g)	<0.0002 to 0.03	0.001 to 0.01[4]
	Pb^{210} (Bq/g)	<0.0005 to 0.05	0.001 to 0.5[5]

1 Ref. 12.

2 for National Uranium Tailings Program Background Study. Values presented are for a range of data for terrestrial fauna.

3 for wet tissue, excluding bone

4 range of means (two studies)

5 range of means

TABLE 10

RADIONUCLIDE VALUES OF DUPLICATE SAMPLES USED FOR QUALITY ASSURANCE

N.C.-212 N.C.-1000(1)

	LIVER	KIDNEY	HEART	MUSCLE	SKIN	BONE
	N.C.-212 / N.C.-1000	N.C.-212 / N.C.-1000	N.C.-212 / N.C.-1000	N.C.-212 / N.C.-1000	N.C.-212 / N.C.-1000	N.C.-212 / N.C.-1000
Pb 210 Bq/g	0.004 / 0.003	0.0005 / 0.001	(0.0005 / -(2)	0.001 / (0.0004	0.004 / -	0.04 / 0.02
Po 210 Bq/g	0.002 / 0.002	0.002 / 0.002	0.0002 / -	0.0003 / 0.0002	0.0007 / -	0.02 / 0.01
Ra 226 Bq/g	0.005 / 0.05	0.01 / 0.05	- / 0.04	(0.005 / 0.05	0.01 / 0.05	0.02 / 0.06
Th Bq/g	(0.1 / (0.1	(0.1 / (0.1	- / (0.1	(0.1 / (0.1	- / (0.1	(0.1 / (0.1
U Bq/g	(0.2 / (0.2	0.3 / (0.2	- / -	(0.2 / (0.2	- / (0.2	(0.2 / (0.2

N.C.-101 : N.C.-1001

	LIVER	KIDNEY	HEART	MUSCLE	SKIN	BONE
	N.C.-101 / N.C.-1001	N.C.-101 / N.C.-1001	N.C.-101 / N.C.-1001	N.C.-101 / N.C.-1001	N.C.-101 / N.C.-1001	N.C.-101 / N.C.-1001
Pb 210 Bq/g	0.005 / -	0.004 / 0.004	0.0006 / (0.0007	0.001 / 0.001	0.004 / 0.002	0.01 / 0.03
Po 210 Bq/g	0.003 / -	0.004 / 0.004	0.0003 / 0.0007	0.0004 / (0.0003	0.002 / 0.001	0.02 / 0.009
Ra 226 Bq/g	0.05 / 0.05	0.03 / 0.07	0.005 / 0.04	0.005 / 0.06	0.03 / 0.04	0.07 / 0.07
Th Bq/g	(0.1 / (0.1	(0.1 / (0.1	(0.1 / (0.1	(0.1 / (0.1	(0.1 / (0.1	(0.1 / (0.1
U Bq/g	(0.2 / (0.2	(0.2 / (0.2	(0.2 / (0.2	0.3 / (0.2	0.4 / 1.0	(0.2 / (0.2

(1) Samples MC-212/MC-1000 and samples MC101/MC 1001 are identical samples, 1 control and 1 study sample. Each was divided in half and sent for analyses under blind sample numbers (1000 and 1001) for quality assurance purposes.

(2) Blank values indicate insufficient tissue sample amounts to conduct the individual analysis.

4.0 CONCLUSIONS

The study area coverage of collected forage and water samples was spatially and temporally adequate to allow for comparison with the moose tissue samples collected at a later time (during the normal open hunting season). However, due to the inherent nature of the subject species during the specific time of year collected, some uncertainty exists as to whether or not the animals taken at each site had in fact spent a reasonable period of time within the area. The public awareness campaign was well received by the public as evidenced by the successful collection of 52 moose tissue samples, as well as the positive attitude expressed by the public to the field collection teams.

Results received from the radionuclide analysis indicated that there was essentially no statistical difference between the concentrations of the study or control animals, vegetation and water samples, although it must be cautioned that the data set used is actually quite small. Concentration factors were also found to be very low. In addition, the values of the analytes were within (below or equal) to background levels in other areas.

5.0 REFERENCES

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APPENDIX 6.1

Public Awareness Campaign

MacLaren Plansearch

ECONOMIC AND SOCIAL STUDIES
ENVIRONMENTAL SCIENCES
TRANSPORTATION STUDIES
COMPUTER SCIENCE
URBAN AND REGIONAL PLANNING
OCEAN SCIENCE AND OPERATIONS
WATER RESOURCES

MacLAREN PLANSEARCH INC
[illegible] YONGE STREET, TORONTO, ONTARIO, CANADA M5E 1E7
TELEPHONE 416 365 [illegible] TELEX 06 23769 CABLE [illegible]

SAMPLE

Dear Hunter,

Our firm is under contract to the Atomic Energy Control Board to carry out an important study on the uptake of radionuclides from water and forage to moose. To do this we need your help in obtaining samples of mature moose from within the shaded area of the map (see enclosed map). The samples required would be 1 to 2 pounds each of liver, kidney, heart, muscle, skin and bone.

In addition, we require control samples from moose which are hunted in areas well outside the Serpent River Drainage area (60 to 70 miles away is preferred).

The Ontario Ministry of Natural Resources are co-operating on this project and have provided us with a listing of those people successful in receiving a mature animal tag within Management Unit 37 for the 1985 hunting season.

If you are interested in participating in this study, please fill in the attached form and return it to us in the enclosed self-addressed envelope. A person from our firm will contact you during the week prior to the opening day of the season to explain the program and give you a set of sample bags. Those who actively participate will receive a complimentary hunting hat.

Thank you for your co-operation and we wish you good luck during the hunting season.

Yours respectfully,

MacLAREN PLANSEARCH INC.

MacLaren Plansearch

INFORMATION REQUEST

Hunter's Name and Address _____

_____

_____

Telephone Number _____

Approximate area where hunt will take place _____

_____

_____

_____

SAMPLE

Time Period: Morning _____

(Best for Contact) Afternoon _____

Evening _____

Further information may also be obtained from:

Lavalin

The Atomic Energy Control Board

and

MacLaren Plansearch Inc.

Need Your Help

in the collection of moose tissue

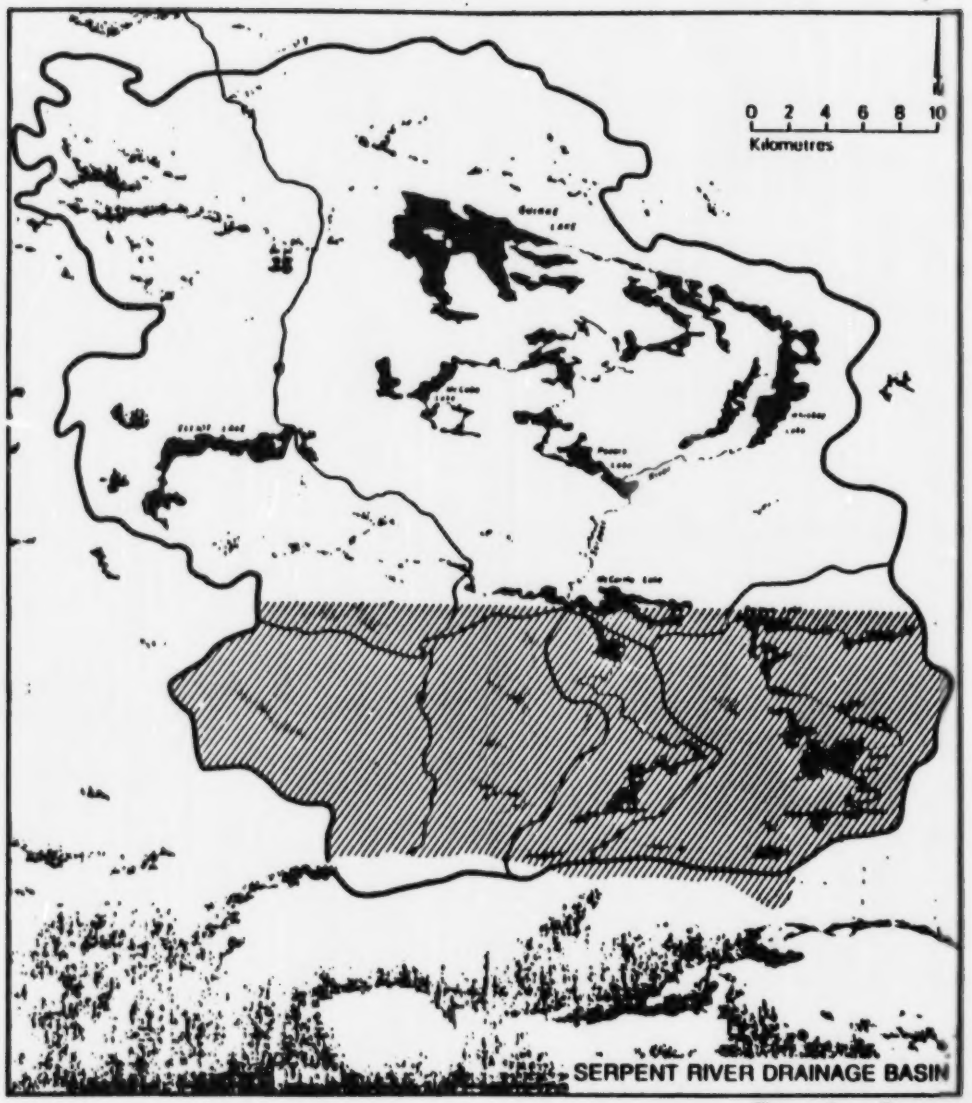
The Atomic Energy Control Board is conducting an important study on the uptake of radionuclides from water and forage to moose. To do this we need samples of mature moose (preferably cows) from within the shaded area on the map (see opposite).

We also need moose samples from well outside the region marked in black, (60 to 70 miles away would be preferred).

Sample bags and a complimentary hunting hat may be picked up at the locations listed on the back of this pamphlet.

Those hunters with a Ministry of Natural Resources mature animal tag who contribute a full set of samples and the completed information sheet will receive one of a limited number of hunting vests.

Please fill out this information sheet



Denotes Active Study Site

Study Area

S A M P L E

Information Sheet

It is very important that this sheet be filled out as completely as possible.

Hunter's Name and Address _____

_____

Location of Kill (mark on attached map)

Sex of Animal and Maturity Cow_____ Bull _____

Approximate Weight _____

Check Samples Submitted

Liver _____

Kidney _____

Heart _____

Muscle _____

Skin _____

Bone _____

Do Not Wash Samples !

- Place approximately 1 to 2 pounds of each item in a separate sample bag.
- Fill in this Information Sheet and put it in a large plastic bag with the smaller sample bags.
- Hand in at one of the locations listed on the back of this pamphlet within three days of kill.

or

- Freeze the samples and contact one of the locations listed for pick-up
- If you have any questions, please contact:

Additional Information

Contact Agencies and Drop-off Points

1. Atomic Energy Control Board
   Algo Inn Shopping Center
   Elliot Lake, Ontario
   Telephone (705) 848-7123

2. Ontario Ministry of Natural Resources
   District Office
   Blind River, Ontario
   Telephone (705) 356-2234

   or, Conservation Officers Office
   Elliot Lake, Ontario

3. Inn On The Lake
   Highway 108
   Elliot Lake, Ontario
   Telephone (705) 848-3611

4. Wheel Inn
   Highway 17
   Serpent River, Ontario
   Telephone (705) 844-9928

ATTENTION

MOOSE HUNTERS !

Serpent River Area

Moose Collection 1985

Participate in this Study and Receive a Complimentary Hunting Hat

MacLaren Plansearch Inc., *under contract to:*
The Atomic Energy Control Board
in cooperation with
Ontario Ministry of Natural Resources

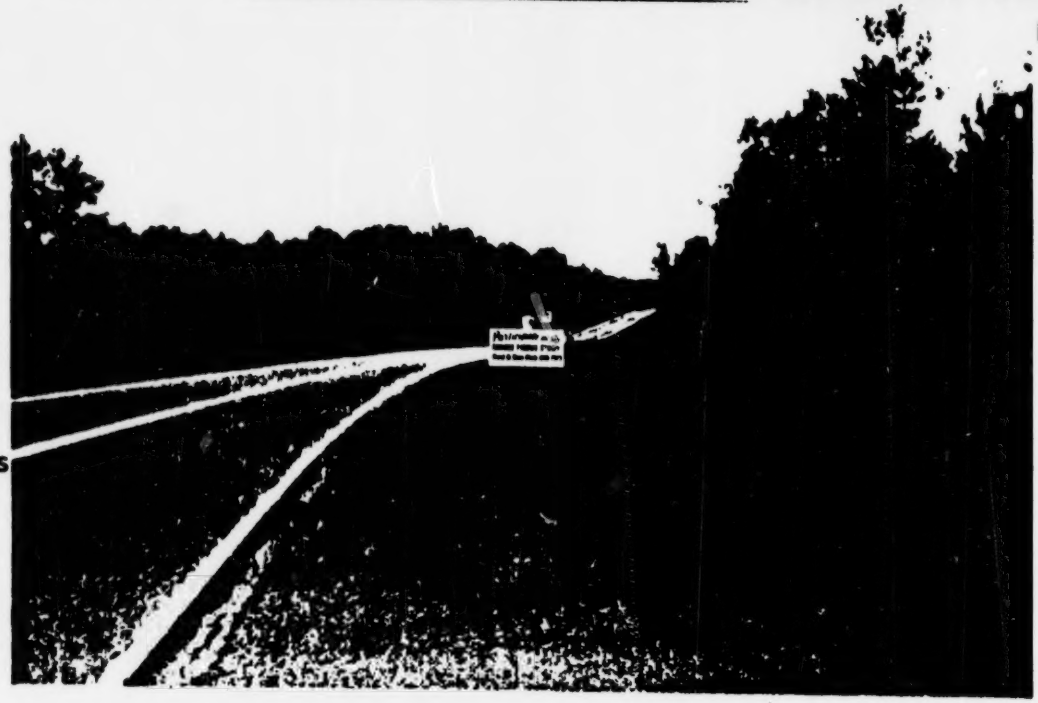
PHOTO #1
MacLaren Plansearch Inc. Mobile Field Unit set up at a temporary sample drop-off and information check station.

PHOTO #2
Promotion package contents including:
-- labelled sampling bags
-- closure ties
-- information pamphlet
-- complimentary hunting hat

PHOTO #3
Hunter incentives include blaze orange hunting hat and vest with identifying study crests.

PHOTO #5
Successful hunter stops at mobile field unit station to submit tissue samples.

PHOTO #4
Participation by local community outdoors club increased sampling range and contact points



APPENDIX 6.2

Analytical Results

TABLE 6.2.1

ANALYTICAL RESULTS ON SELECTED MOOSE TISSUE SAMPLE[1]

MACLAREN SAMPLE #	SRC SAMPLE #	TISSUE DESCRIPTION	PHYSICAL PROPERTIES		RADIONUCLIDES			SLOW POKE	
			Ash wt (g)	Total wt (g)	Pb 210,t1 Bq/g	Po 210,t1 Bq/g	RA 226,t1 Bq/g	Th,NAA ug/g	U,NAA ug/g
M.C.-H.M.1	1619	KIDNEY	2.5	250	0.001	0.003	0.04	0.1	0.2
M.C.-H.M.1	1620	HEART	1.1	143	0.001	0.001	0.02	0.1	0.2
M.C.-H.M.1	1621	MUSCLE	2.6	310	0.0008	0.0004	0.02	0.1	0.2
M.C.-H.M.1	1622	LIVER	0.5	121	0.004	0.006	0.18	0.1	0.2
M.C.-H.M.1	1623	SKIN	1.8	265	0.0007	0.0006	0.05	0.1	0.6
M.C.-H.M.2	1624	KIDNEY	3.1	386	0.002	0.001	0.04	0.1	0.1
M.C.-H.M.2	1625	HEART	0.8	97	0.001	0.0004	0.04	0.1	0.2
M.C.-H.M.2	1626	MUSCLE	1.5	133	0.001	0.0004	0.08	0.1	0.5
M.C.-H.M.2	1627	LIVER	3.9	357	0.002	0.004	0.04	0.1	0.4
M.C.-H.M.2	1628	SKIN	1.6	201	0.002	0.002	0.15	1	1.8
M.C.-H.M.2	1629	BONE	96	212	0.02	0.02	0.05	0.1	0.2
M.C.-J.G.	1631	KIDNEY	2.7	300	0.01	0.004	0.09	0.1	0.2

[1] Results as reported by Saskatchewan Research Council

M.C.-J.G.	1633	HEART	1.9	212	0.001	0.0002	0.02	0.1	0.2
M.C.-J.G.	1630	LIVER	2	144	0.002	0.002	0.07	0.1	0.5
M.C.-J.G.	1634	MUSCLE	2.3	165	0.001	0.0006	0.02	0.1	0.7
M.C.-J.G.	1632	SKIN	2.2	266	0.001	0.002	0.03	1.4	0.5
M.C.-J.G.	1635	BONE	74	180	0.006	0.004	0.03	0.1	0.4
M.C.-L.P.	1636	KIDNEY	4.8	411	0.004	0.01	0.07	1.1	0.2
M.C.-L.P.	1638	HEART	5	579	0.0009	0.001	0.07	0.1	0.4
M.C.-L.P.	1639	LIVER	15.7	1053	0.001	0.009	0.05	0.1	0.4
M.C.-L.P.	1637	MUSCLE	4.1	469	0.001	0.0006	0.03	1.9	0.2
M.C.-L.P.	1640	BONE	141	349	0.03	0.03	0.06	0.1	0.2
M.C.-L.P.	1641	SKIN	2.4	290	0.004	0.005	0.11	2.8	3.8
M.C.-204	1642	KIDNEY	4.3	418	0.001	0.006	0.04	0.1	0.2
M.C.-204	1643	HEART	6.1	661	0.0009	0.001	0.09	0.1	0.2
M.C.-204	1644	LIVER	5.9	485	0.003	0.009	0.08	0.1	0.6

TABLE 6.2.1 (cont'd)

M.C.-204	1646	MUSCLE	1.8	197	0.001	0.0004	0.1	0.1	0.2
M.C.-204	1647	BONE	180	391	0.03	0.007	0.05	0.1	0.2
M.C.-211	1649	KIDNEY	6.5	611	0.002	0.01	0.09	0.1	0.2
M.C.-211	1648	HEART	3.7	364	0.0009	0.0008	0.04	0.1	0.2
M.C.-211	1650	LIVER	5.2	391	0.006	0.01	0.07	0.1	0.2
M.C.-211	1651	MUSCLE	2.6	345	0.001	0.0007	0.05	0.1	0.2
M.C.-211	1652	SKIN	3.4	538	0.001	0.003	0.02	0.1	1.2
M.C.-211	1653	BONE	95	332	0.05	0.03	0.11	0.1	0.2
M.C.-162	1654	KIDNEY	4.5	466	0.006	0.006	0.1	0.1	0.7
M.C.-162	1656	HEART	3.8	456	0.001	0.0009	0.06	0.1	0.2
M.C.-162	1657	LIVER	4.6	394	0.02	0.02	0.12	0.1	0.3
M.C.-162	1655	MUSCLE	4.4	470	0.001	0.0008	0.05	0.1	0.2
M.C.-162	1658	SKIN	4	374	0.005	0.007	0.2	19.6	16.4
M.C.-162	1659	BONE	126	251	0.03	0.03	0.3	0.1	0.2

M.C.-212	13901	KIDNEY	3.3	330.2	0.0005	0.002	0.01	0.1	0.3
M.C.-212	13899	HEART	-	-	0.0005	0.0002	-	-	-
M.C.-212	13898	LIVER	6.6	713.7	0.004	0.002	0.005	0.1	0.2
M.C.-212	13900	MUSCLE	4.3	461.6	0.001	0.0003	0.005	0.1	0.2
M.C.-212	13902	SKIN	0.7	91.9	0.004	0.0007	0.01	-	-
M.C.-212	13897	BONE	98.7	262.3	0.04	0.02	0.02	0.1	0.2
M.C.-101	13907	KIDNEY	3.4	394.6	0.004	0.006	0.03	0.1	0.2
M.C.-101	13905	HEART	3	333.7	0.0006	0.0003	0.005	0.1	0.2
M.C.-101	13904	LIVER	5.4	467.5	0.005	0.03	0.03	0.1	0.2
M.C.-101	13906	MUSCLE	4.4	479.8	0.001	0.0004	0.005	0.1	0.3
M.C.-101	13908	SKIN	3.5	587.4	0.004	0.002	0.03	0.1	0.4
M.C.-101	13903	BONE	74	207.8	0.01	0.02	0.07	0.1	0.2
M.C.-140	13436	KIDNEY	6.5	662.4	-	-	0.03	-	-
M.C.-140	13434	LIVER	5.9	600.7	-	-	0.04	-	-

M.C.-140	13435	MUSCLE	2.3	232.5	-	-	0.005	-	-
M.C.-140	13445	SKIN	3.6	755.2	-	-	-	0.1	0.6
M.C.-140	13433	BONE	-	-	-	-	-	-	-
M.C.-017	13440	KIDNEY	4.3	465.9	-	-	0.05	-	-
M.C.-017	13438	LIVER	5	648.9	-	-	0.01	-	-
M.C.-017	13439	MUSCLE	2	246.1	-	-	0.02	-	-
M.C.-017	13446	SKIN	4.1	580	-	-	-	0.1	0.2
M.C.-017	13437	BONE	258	510.8	-	-	0.11	-	-
M.C.-115	13444	KIDNEY	8.1	737.7	-	-	0.02	-	-
M.C.-115	13442	LIVER	6.2	687.7	-	-	0.03	-	-
M.C.-115	13443	MUSCLE	1.6	196.1	-	-	0.01	-	-
M.C.-115	13447	SKIN	4.4	662.4	-	-	-	0.1	1.4
M.C.-115	13441	BONE	224.3	467.2	-	-	0.1	-	-

TABLE 6.2.2

ANALYTICAL RESULTS ON SELECTED FORAGE SAMPLES[1]

MACLAREN SAMPLE #	SRC SAMPLE #	VEGETATION TYPE	ASH WEIGHT(g)	DRY WEIGHT(g)	WET WEIGHT(g)	MOISTURE %	Ra 226	STUDY/CONTROL SAMPLE	ASSOCIATED MOOSE SAMPLES
TB-7	13449	Bw	3.9	77.2	185.7	58.4	0.3	STUDY	M.C.-H.M.1; -H.M.2; -J.G.
TB-9	13450	Fb	3	99.8	240.9	58.6	0.18	STUDY	M.C.-H.M.1; -H.M.2; -J.G.
TB-8	13451	Mm	4.7	41.3	384.7	89.2	0.45	STUDY	M.C.-H.M.1; -H.M.2; -J.G.
TA-15	13452	Fb	2.8	93.3	230	59.4	0.3	STUDY	M.C.-L.P.
TA-16	13453	Bw	4.2	125.9	300.5	58.1	0.7	STUDY	M.C.-L.P.
PA-12	13454	Y.W. Lily	2.5	26.2	505.6	94.8	0.5	STUDY	M.C.-L.P.
TA-1	13455	Bw	4.2	107.5	266.6	59.7	0.35	STUDY	M.C.-204
TA-2	13456	Fb	4.2	158.5	390.9	59.5	0.25	STUDY	M.C.-204
PA-3	13457	Pick. Weed	4.8	154.6	406.6	62	0.07	STUDY	M.C.-204
PA-4	13458	Y.W. Lily	6.4	64.4	636.1	89.9	0.45	STUDY	M.C.204
TA-13	13459	Fb	3.4	103	245.9	58.1	0.2	STUDY	M.C.-115
TA-14	13460	Bw	4.1	96.4	266.2	63.8	0.25	STUDY	M.C.-115
L.W. RIVER	13465	Bw	1.8	105.2	187.6	43.9	0.6	CONTROL	M.C.-017

[1] Results as reported by Saskatchewan Research Council

L.W. RIVER	13466	Fb	4.8	163.8	374	56.2	0.7	CONTROL	M.C.-017
W.L.W. RIVER	13467	Bw	2.9	154.3	272.1	43.3	3	CONTROL	M.C.-017
W.L.W RIVER	13468	Fb	3.7	143.2	312.6	54.2	1	CONTROL	M.C.-017
SQUARE LAKE	13469	Bw	3	135.4	247.1	45.2	3.5	CONTROL	M.C.-211; -162; -140
V-C-S-1	18647	Fb	16.9	411	901	54.4	0.11	CONTROL	M.C.-212
V-C-S-2	18648	Bw	13.1	268	787	65.9	0.14	CONTROL	M.C.-212
V-C-S-3	18649	Y.W. Lily	10.3	118	724	83.7	0.06	CONTROL	M.C.-212

TABLE 6.2.3

ANALYTICAL RESULTS ON SELECTED DRINKING WATER SAMPLES[1]

MACLAREN SAMPLE #	SRC SAMPLE #	WATER SAMPLE	ASH WEIGHT (gm)	TOTAL WEIGHT (gm)	Bq/l ANALYTE Ra 226	Ur	Th	STUDY/CONTROL SAMPLES	ASSOCIATED MOOSE SAMPLES
WA-1 SEPT 8/85	13002	LILLIE LK. BL CREEK INLET	-	-	0.005	-	-	STUDY	M.C.-204
WA-6 SEPT 5/85	13003	-	-	-	0.005	-	-	STUDY	M.C.-115
WA-7 SEPT 8/85	13004	-	-	-	0.005	-	-	STUDY	M.C.-L.P.
WA-5 SEPT 7/85	13005	CAMP L.	-	-	0.06	-	-	STUDY	M.C.-H.M.1; -H.M.2; -J.G.
W.L.W RIVER	13006	W.L.W. RIVER	-	-	0.005	-	-	CONTROL	M.C.-017
L.W.RIVER N.W. KAM TWP	13007	L.W. RIVER	-	-	0.005	-	-	CONTROL	M.C.-017
PORT LK.	13000	PORT LK	-	-	0.005	-	-	CONTROL	M.C.-140
SQUARE LK	13009	SQUARE LK	-	-	0.015	-	-	CONTROL	M.C.-140
W-C-S-1	18646	SULTAN	-	-	0.005	-	-	CONTROL	M.C.-212

[1] Results as reported by Saskatchewan Research Council

APPENDIX 6.3

Statistical Tests

APPENDIX 6.3

STATISTICAL TESTS

F-test for Equality of Population Variances[7]

This procedure is followed to test for the equality of population variances (s).

Example: Pb^{210} in kidney

The hypothesis being tested is:

H_o: population variances s_1 and s_2 are the same.

For this test s_1 and s_2 are defined as

s_1 = largest observed standard deviation (for sample size = n_1)

s_2 = other observed standard deviation (for sample size = n_2)

In this example

$s_1 = \log (3.474) = 0.5408$ $n_1 = 3$

$s_2 = \log (2.466) = 0.392$ $n_2 = 6$

The test statistic is calculated from

$$F = s_1^2/s_2^2$$

$$= \frac{0.5408^2}{0.392^2} = 1.90$$

For the F test, the degrees of freedom are $n_1 - 1$ and $n_2 - 1$. In this example they are 2 and 5.

Therefore the critical F value for this example. obtained from standard F - distribution tables, is

$$F_{0.05,\ 2.5} = 5.79$$

Since $1.9 < 5.79$ we accept the hypothesis that the population variances are the same for concentrations of Pb^{210} in kidneys for the study and control groups.

Test for Study Group Concentration Greater than Control Group

Case I: equal population variance

Example: Pb^{210} - kidney

This procedure is used for data sets that were shown to have equal population variance (see previous test).

In this case the following hypothesis is tested:

H_0: concentrations in the study group are equal to the concentration in the control group (i.e. $U_{study} = U_{control}$)

The following procedure was followed:

Let X_1 = log (mean) of the study group

$= -2.582$ $(n_1 = 6)$

X_2 = log (mean) of the control group

$= -2.740$ $(M_2 = 3)$

and s_1 = log (variance) of study group

$= 0.392$

s_2 = log (variance) of the control group

$= 0.5408$

The pooled variance of the data as calculated from

$$s^2 = \frac{(n_1 - 1)\, s_1^2 + (n_2 - 1)\, s_2^2}{n_1 + n_2 - 2}$$

for our example

$$s^2 = \frac{5.(0.392)^2 + 2.(0.5408)^2}{7}$$

$$= 0.1933$$

Therefore $s = 0.4396$

The test statistic is given by

$$t = \frac{X_1 - X_2}{(n_1 + n_2)^{1/2} \cdot s}$$

for our example

$$t = \frac{-2.582 + 2.740}{(0.7071)\cdot(0.4396)}$$

$$= 0.508$$

at a 95% confidence; the critical t value, from standard tables is

$t_{-0.025,7} = 2.365$

since $/0.508/ < 2.365$

H_0 is accepted.

In other words, the Pb^{210} concentration in the kidneys of the study group are the same as the controls.

Case II: non-equal population variance[8]

Example: Po^{210} in muscle

In this situation, the Welch approximation was used to calculate a modified degree of freedom.

For our example

(study group) $X_1 = -3.3392$ $(n_1 = 6)$

(control group) $X_2 = -3.2582$ $(n_2 = 3)$

$S_1 = 0.0909$

$S_2 = 0.2310$

with the hypothesis H_0: $u_1 = u_2$

a new degree of freedom is calculated from

$$m = \frac{\left(\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}\right)}{\frac{\frac{(s_1^2)^2}{n_1}}{n_1 - 1} + \frac{\frac{(s_2^2)^2}{n_2}}{n_2 - 1}}$$

for our example

$m = 2.316$

in cases where the m value is non-integer, the next lowest integer value is used i.e. $m = 2$.

The test statistic is given by

$$t = \frac{X_1 - X_2}{\sqrt{\frac{s_1^2}{n_2} + \frac{s_2^2}{n_2}}}$$

which for this example gives

$t = -0.585$

From standard tables, the critical t value at 95% confidence is

$t = 4.303$

since $-0.585 < 4.303$ we accept the hypothesis that the means are the same.

Mann Whitney Test[10]

Example: Pb^{210} in kidney

In the test the actual data are not used, but the rank of the data in the overall data set is used.

For consistency with standard text books on the subject, the negative hypothesis was tested. In other words,

H_0 = Concentrations are not higher in the study group than in the control group.

Data is ranked highest to lowest. In cases of tied rank, an average rank is given to each data point.

The sum of the ranks (R_1, R_2) are then calculated.

Study (n = 6)		Control (n = 3)	
Data	Rank	Data	Rank
0.001	7.5	0.002	5.5
0.002	5.5	0.006	2.0
0.01	1.0	0.0005	9.0
0.004	3.5		
0.001	7.5	R_2 =	16.5
0.004	3.5		
R_1 =	28.5		

The Mann Whitney statistic is then calculated from,

$$U = n_1 \cdot n_2 + \frac{n_1(n_1 + 1)}{2} - R_1$$

$$= 6.3 + \frac{6.7}{2} - 28.5$$

$$= 10.5$$

From standard tables,

$U_{0.025,3,6} = 17$

since $10.5 < 17$, accept H_0

The Pb^{210} concentrations in the kidney of the study group were not higher than Pb^{210} concentrations in the livers of the control group at a 97.5% confidence.

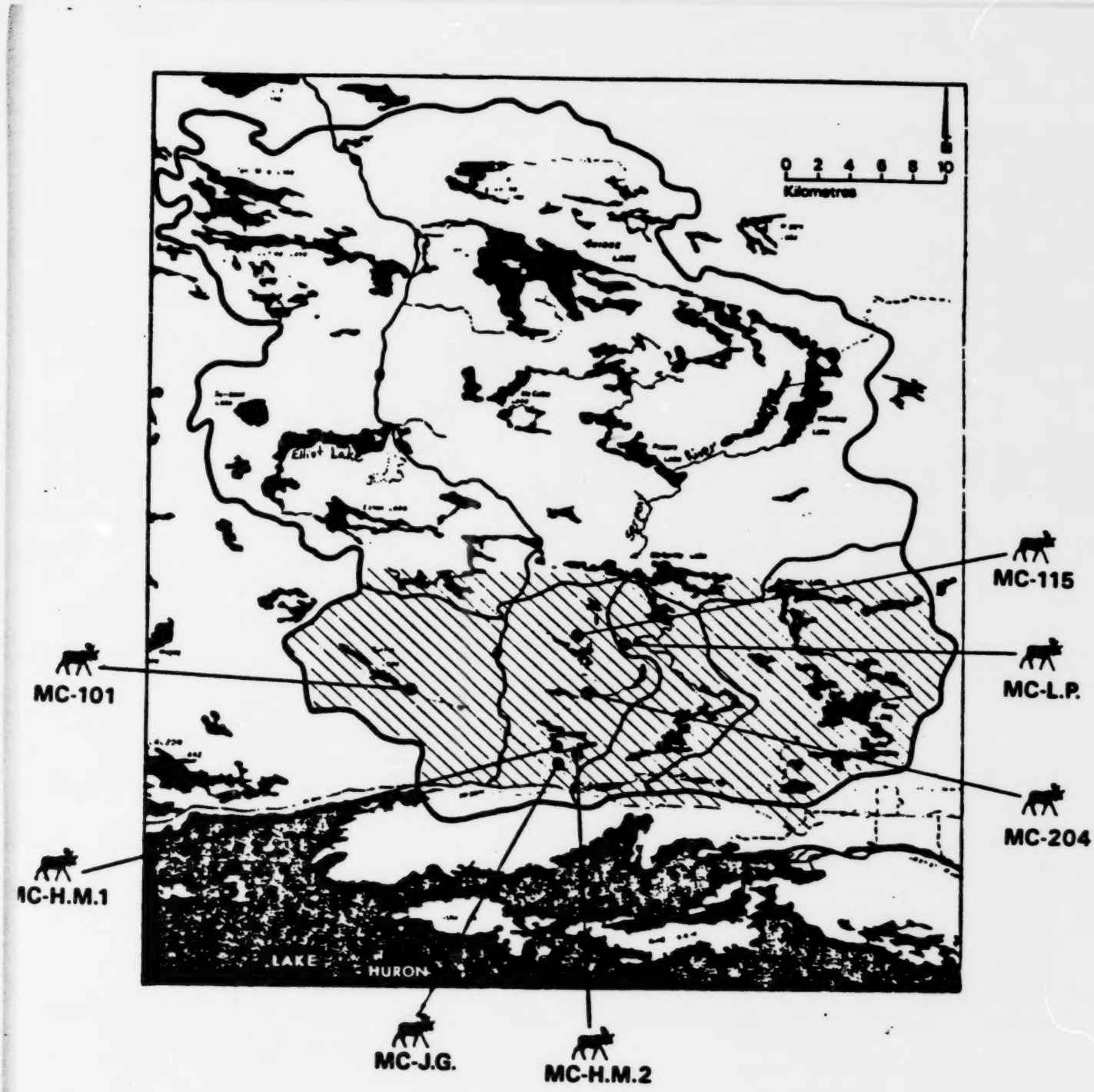
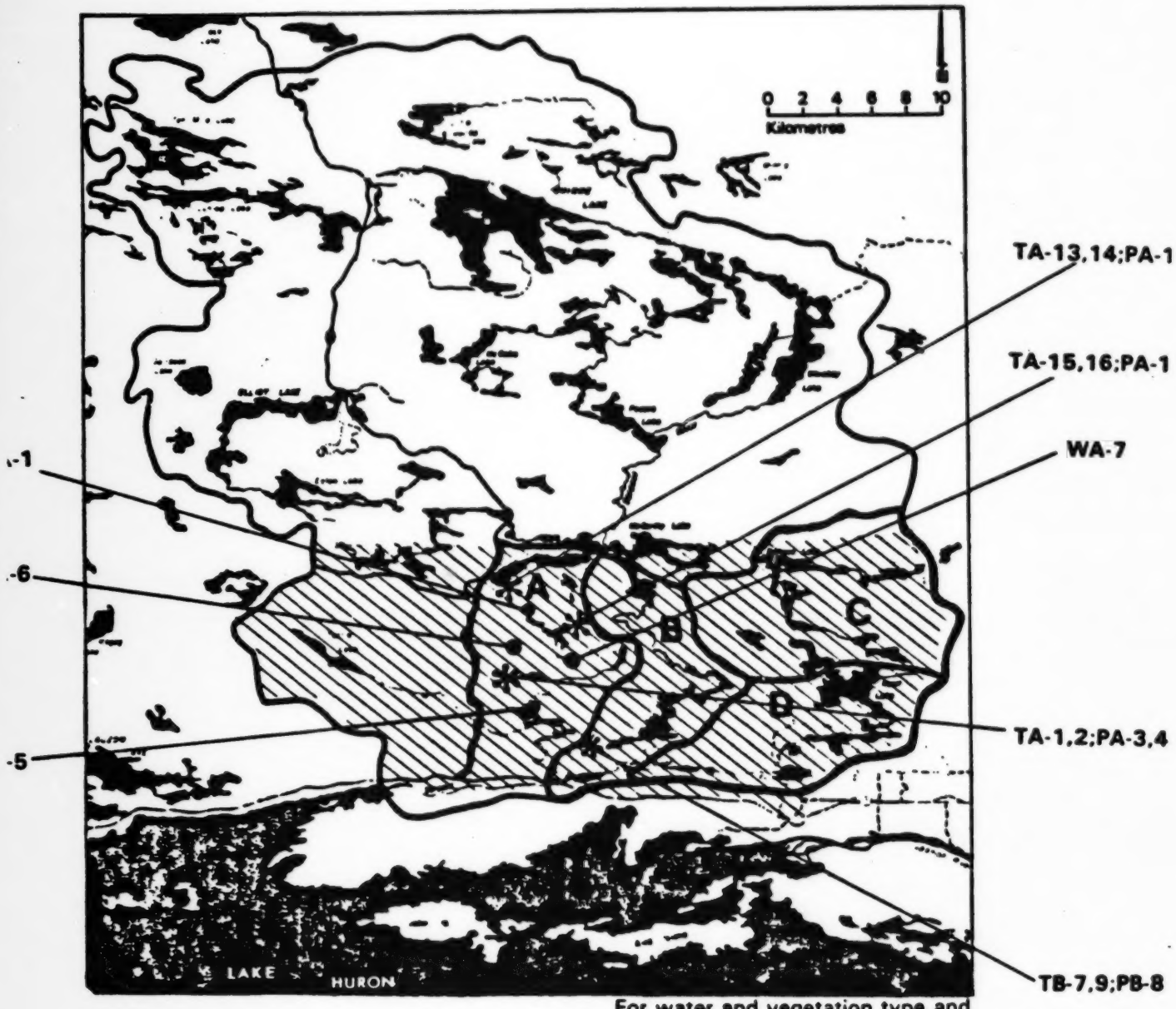


Figure 1
Moose Kill Site Locations for Radionuclide Analysed Tissue Samples

(Full-sized original maps in AECB Library.)



For water and vegetation type and associated tissue samples refer to tables in text

Figure 2
Sample Site Locations for Radionuclide Analysed Forage and Water Samples
(Associated to Analysed Tissue Samples)

Vegetation Samples *

Water Samples ●

(Full-sized original maps in AECB Library.)